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AUTOMATED TANK GAUGING FOR HYDROCARBON STORAGE SYSTEMS – AN EXPERIMENTAL APPROACH

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ABSTRACT

The Oil and Gas industries are situated all around the globe in various remote locations, where there is crude or natural gas to be extracted. These locations are subjected to extreme weather conditions going above 50ºC all the way down to -30ºC. During transit of petroleum product from one location to another location, their temperature influences the volume and leads to financial loss. The error free measurement of the hydrocarbon storage volume with highest accuracy is the need of the petroleum industry. The current volume correction methods introduced are manual and involve more human interventions and leads to error. The objective of this paper is to observe the volume of a storage tank on the field and create a device, which reports the stored hydrocarbon volume by measuring the density, average temperature. The average temperature is computed using multipoint temperature sensor. Based on the parametric evaluation of the density, average temperature of the stored hydrocarbon volume correction factor is calculated automatically, considering the petroleum standards. This enables to measure accurate volume measurement and minimizes the error losses occurring due to temperature changes in the stored hydrocarbon. The proposed automatic system is tested experimentally and compared with the manual calculation system and observed to be highly efficient. The developed customized software system is able to reduce the human errors and volume estimation time.

KEYWORDS: *Oil & Gas Industries Storage Systems, Automatic Tank Gauging, Level Transmitter, Temperature Transmitter & Temperature Fluctuation*

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Original Article

1. INTRODUCTION

Significant losses of liquid hydrocarbons happen due to their temperature fluctuations during storage. According to some estimates, minimum 5% of oil produced in Russia is lost on its way to consumers, which is approximately 25 million ton per year. About a quarter of these losses are caused by their temperature fluctuations during storage (**Ed Yu D Zemenkov, 2014**).

Based on literature analysis and expert evaluation, it was discovered that the primary cause of oil product temperature changes in the tank is ambient temperature (**Levetin and Yu D Zemenkov, 2016**).

The rate of temperature change of the gas phase depends on the ability to absorb and emit radiant energy incident on the tank wall, on the outside temperature drop and velocity. In this regard, there was a practical interest in determining the effect of daily temperature fluctuations on thermal oil product fluctuations. To do this, at different levels of the tank were installed temperature sensors, with temperature measurement results (**Patent 2500486 RU, 2013**).

Temperature measurement is often neglected and the need for accuracy understated. Typical hydrocarbons have a relatively large thermal expansion coefficient when compared to chemicals and most other liquids. The required correction factor, also called Volume Correction Factor or VCF, is close to 0.1% per °C. As a result, a 0.25 °C temperature assessment error induces an error in excess of 3 mm in a 36 m diameter tank (with 15 meters of product). The temperature uncertainty is caused both by the measurement accuracy, and how well the temperature sensor is installed, in order to measure a representative product temperature. Average temperature measurement with a multi-element temperature sensor is the best solution. Modern averaging temperature sensors have up to sixteen elements, can be installed from the tank roof and have an accuracy of 0.1 °C.(**Endress + Hauser, 2015**)

The use of standard temperature is imposed in the measurement of volume of petroleum products for the purpose of marketing and comparing with the imported fuel. In the USA AND Europe, the standard temperature in volume correction is in 15°C. However in India, since most of the crude are imported the standard temperature would be 15°C.

Manually converting the measured volume of petroleum product to standard temperature is time consuming process, resulting in serious errors leads to false physical stock. This paper will focus on reducing the human errors by introducing an Automatic Tank Gauging system with customized software to perform volume correction at standard temperature precisely and efficiently.

2. NEED FOR TANK GAUGING

Tank gauging is required to determine the physical quantity of petroleum products obtained in a storage tank. The importance will be multifold during volume calculation of imported petroleum product, since money will change hands based on the results. The measured volume will also be used for inventory control.

Figure 1 represents the steps involved in the process of volume calculation and cost calculation of the stored petroleum product.

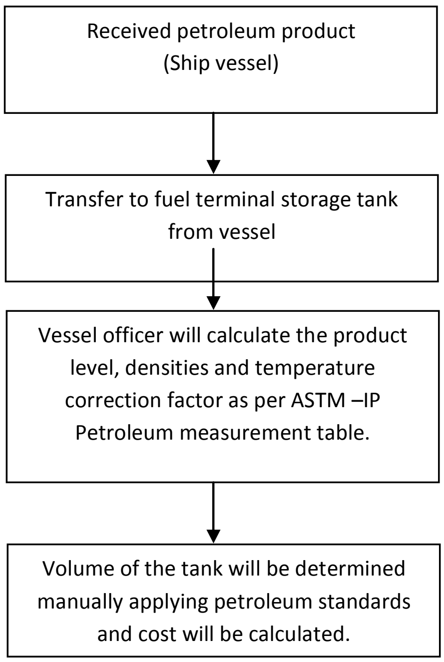

Figure 1: Process Steps in Volume/Cost Calculation of the Stored Petroleum Product

2.1 Volume Correction – Indian Standards

IS 2164, 1961 states the Indian Standards on tank calibration, gauging, sampling, temperature measurement and determination of density have laid down procedures which, when followed, allow the volume, temperature and density of a bulk quantity of oil to be determined with considerable precision.

The accepted volume is correct implies that the following standards are followed:

- For vertical and horizontal tanks, the recommendations laid down in the following standards shall apply:

  IS: 2007-1961 Method For Calibration Of Vertical Oil Storage Tanks

  IS: 2008-1961 Method for Computation of Capacity Table for Vertical Oil Storage

  IS: 2166-1963 Method for Calibration of Horizontal and Tilted Oil storage Tanks

  IS: 1518-1960 - the oil depth has been correctly measured and recorded by the methods laid down in Method for Gauging of Petroleum and Liquid Petroleum Products.

- The accepted oil temperature is substantially correct and has been obtained in accordance with the recommendations laid down in IS: 15 19 (Part I)-1961 Method for Temperature Measurement of Petroleum and Its Products, Part I; and

- All densities have been determined in accordance with the method for determination of density laid down in P: 16 of IS: 1448 (Part I)-I960 Methods of Test for Petroleum and Its Products, Part I.

2.1.1 Volume Correction – A Typical Example (Indian Scenario)

Figure 2 shows the procedural steps involved in calculation of volume at the accepted temperature, calculation of volume at the standard reference temperature (Figure 4) and calculation of volume at accepted temperature (cases of temperature differing before and after movement - Figure 5) .

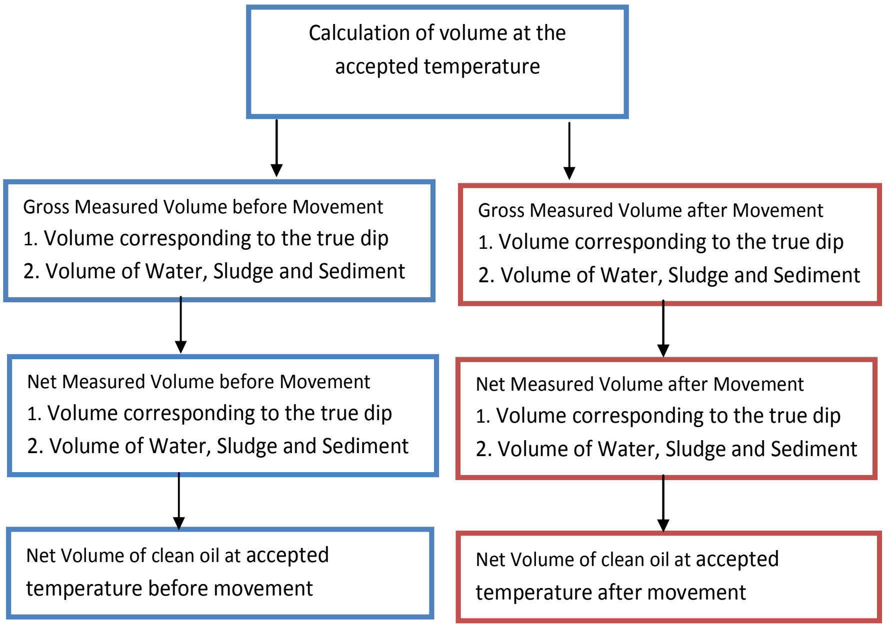

Figure 2: Calculation of Volume at the Accepted Temperature

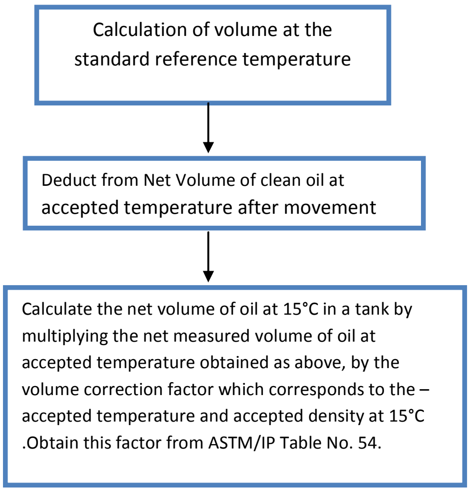

Figure 3: Calculation of Volume at the Reference Temperature

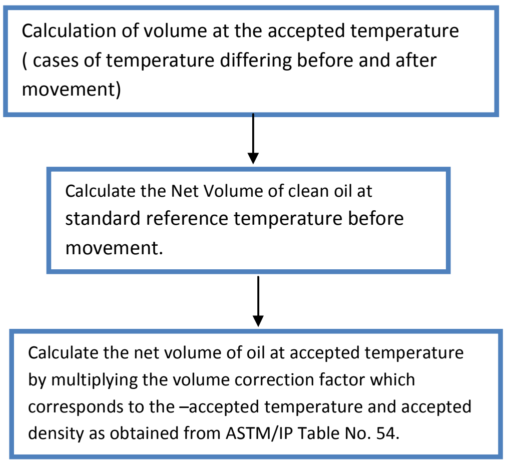

Figure 4: Calculation of Volume at the Accepted Temperature (Cases of Temperature Differing Before and after Movement)

From Table 1, it can be observed that the net measured volume differs between observed temperature and reference temperature. It is a practice to calculate cost based on net volume at reference temperature (15°C).

Table 1: An Example Volumetric Parameterization Considering Temperature

Description of Parameters	Delivered Volume at the Observed Temperature	Delivered Volume at the Reference Temperature
Temperature	26°C	15°C
Density at 15°C (ASTM/IP Table No. 53)	0.707 9 kg/l	0.716 3 kg/l
Factor to reduce volume to 15°C (ASTM/IP Table No. 54)	NA	0.9869
Net measured volume	9150000 Litres	9030135 Litres

2.1.2 Volume Correction – A Typical Example (Cases of Temperature Differing Before and After Movement)

In some cases, there is a possibility of temperature difference of the petroleum product before delivery and after delivery due to movement of the petroleum product between two places of different climatic conditions. The recommended procedure for calculating the volume of gasoline at accepted temperature when ‘before delivery’ and ‘after delivery ’ temperature are different is enumerated below with a numerical example.

Net measured volume before delivery at 26°C = 13 000 litres

Net measured volume after delivery at 23°C = 4 500 000 litres

When the before and after delivery temperatures differ, the accepted temperature shall be the weighted average of these two temperatures as shown in (1)**.**

$$T_{Average} = \frac{V_{T_{26°C}} + V_{T_{23°C}}}{V_{T_{26°C}} + V_{T_{23°C}}} \tag{1}$$

$$T_{Average} = \frac{13000000 \times 26 + 4500000 \times 23}{17500000} = 25.2\ °C$$

$$V_{T_{Observed}} = 8500000 \text{ Litres} \tag{2}$$

Volume Correction Factor at 25.2 °C = 0.9875 (ASTM/IP Table No. 54)

$$V_{T_{Average}} = \frac{8500000}{0.9875} = 8607595 \text{ Litres} \tag{3}$$

From (2) the observed volume is 8500000 Litres.

The average volume is observed to be 8607595 Liters from (3). It shows that the calculation of volume considering temperature fluctuation is a complex process and leads to error if done manually. Hence automatic calculation are in high demand. In the next section, an automated tank gauging system is presented which reduces time and error in volume calculation.

3. EXPERIMENTAL ANALYSIS

3.1 Automatic Tank Gauging – Experimental Setup and Hardware

The hardware implementation of the experimental setup (Figure 5) to estimate volume is effected with a multipoint spot temperature sensor (Rosemount 565), Temperature transmitter (Rosemount 2240S), Radar Level gauge (Rosemount 5900S) and Rosemount 3051S - Pressure sensor. (**Rosemount™ Tank Gauging System, 2016**)

The signals from the various sensors are processed at the multichannel Data Acquisition System, and processed further for calculating the net volume after temperature correction by customized software developed by the authors.

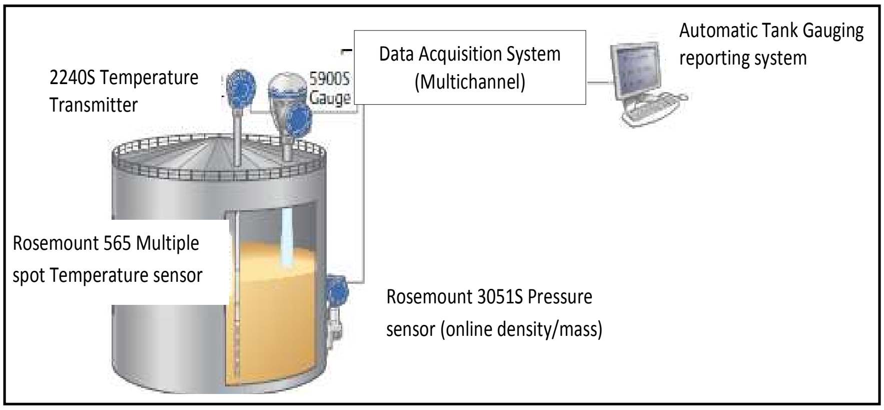

Figure 5: Hardware Implementation of the Experimental Setup

3.2 Automatic Tank Gauging – Software implementation

The objective of automated tank gauging is to develop a device that can estimate the volume of the petroleum product at 15°C without referring the ASTM tables and without human intervention. In some cases, the volume calculation involves multiple volume calculations to equate or average temperatures at particular geographical location. The system is developed using Microsoft excel (PLX DAQ Excel), which operates with zero license fee. The developed system is simple to use, highly portable and designed with accommodating ASTM tables of petroleum products for the calculation of

- VCF at 15°C (ASTM 54B),
- VCF at 30°C(ASTM 54B)
- Density at 30°C (ASTM 53B)

Figure 6 depicts the process involved in the design of the software to calculate volume by adopting temperature and density standards.

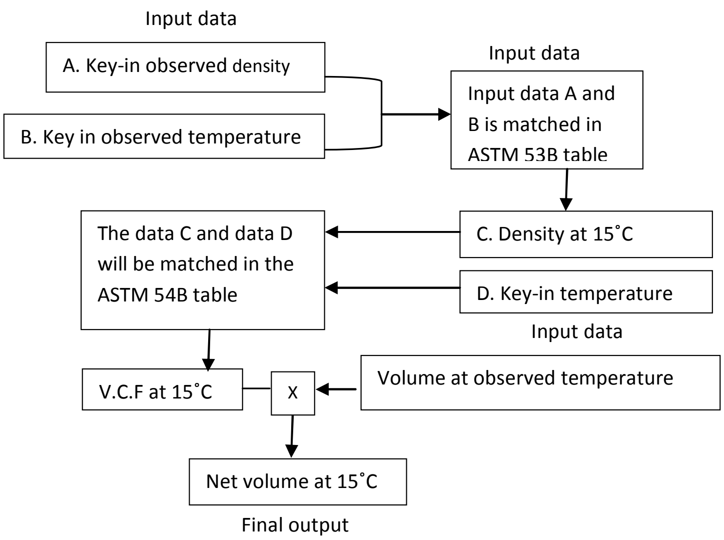

Figure 6: Flow Chart for Customized Software Implementation – Automated Tank Gauging (Shaharin A. Sulaiman et.al, 2011)

4. RESULTS AND DISCUSSIONS

The developed system was tested for its accuracy and repeatability. The automated tank gauging results were compared with the manual system.

Table 2 shows the calculated data from tanks 1, 2, 3 of Motor Gasoline (MOGAS). The manual calculation is done as per standard procedure. The automated tank gauging is done as per procedure explained in Figure 5 with tank capacity of 3000 Litres.

Table 2: Calculated Data from Tank 1, 2 and 3 of Motor Gasoline (MOGAS)

Tank No.	Approximate Volume (L)	Tank Temperature (°C)	Product Density (kg/l)	Observed Temperature (°C)
1	1450	29.00	0.7630	29.50
2	1540	28.00	0.7650	27.50
3	1650	28.00	0.7650	29.00

Table 3 shows the actual value of the Product Density at 15°C(kg/l), VCF at (15°C), Volume at 15°C (L) obtained from manual calculation and automated calculation.

Based on Table 3, it is shown that there is considerable matching between the manual and automated tank gauging values. The variation between the physical and automated estimation in tank 1 is 2 Litres. The difference between the physical and automated estimation in tank 2 is 1 Litres. . The difference between the physical and automated estimation in tank 3 is 2 Litres. On further study, it is identified that the human error caused resulted in error.

Additionally, the time taken to compute the volume for 3 tanks is around 7 times of that to calculate from single tank. It is observed that the automated system is 6.3 minutes faster than manual calculation for one tank. Hence, a significant time saving is achieved which improves the cost benefit and quality of work.

Table 3: Calculated Volume from Tank 1, 2 and 3 of Motor Gasoline (MOGAS)

Tank No.	Product Density - 15°C (kg/l)	VCF at (15°C)	Volume at 15°C (L)
Manual Calculation			
1	0.7630	0.98363	1426
2	0.7650	0.98484	1516
3	0.7650	0.98480	1624
Automated Calculation			
1	0.7630	0.98363	1424
2	0.7650	0.98484	1517
3	0.7650	0.98480	1626

5. CONCLUSIONS

The software based automated volume calculation of petroleum products can help to achieve accurate cost estimation, more time saving and appreciable quality of work at fuel terminals. The proposed system with customized free software tools reduces the human miscalculation errors. The experimental results have proven that the automated system is 6.3 minutes faster than manual calculation for one tank.

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